Chapter 26. Sediment Management — Table of Contents

Tables

Figures

Boxes

Chapter 26. Sediment Management

> The management of sediment in river basins and waterways has been an important issue for water managers throughout history – from the ancient Egyptians managing sediment on floodplains to provide their crops with nutrients, to today's challenges of siltation in large reservoirs. The changing nature of sediment issues, due to increasing human populations (and the resulting changes in land use and increased water use), the increasing prevalence of man-made structures such as dams, weirs and barrages and recognition of the important role of sediment in the transport and fate of contaminants within river systems has meant that water managers today face many complex technical and environmental challenges in relation to sediment management.
>
> International Sediment Initiative, Technical Documents in Hydrology 2011

Sediment in California is a valuable resource when it is properly managed, which results in multiple water benefits, environmental health, economic stability, and coastal safety. Sediment definitions vary among the professional disciplines. Sediment, as reflected in this resource management strategy, is composed of natural materials and used contextually as follows:

1. Geology considers sediment to be the solid fragmented material such as silt, sand, gravel, chemical precipitates, and fossil fragments that have been transported and deposited by water, ice, or wind or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface. Sedimentary rocks consist of consolidated sediment.
2. The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) regard sediment as material such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Sediments can come from anywhere and be just about anything. Organic and inorganic material alike can become bits of matter tiny enough to be picked up and carried along with a moving fluid. Organic sediments are mostly debris from trees, plants, grasses, animals, fish, and their waste products. Inorganic sediments are divided into two main groups; coarse-grained sediments and fine-grained sediments. Coarse-grained sediments are boulders, cobbles, gravel, and sand. Fine-grained sediments are silts and clays. Sediment deposits, like tree rings, can serve as a record of natural history.

A further important distinction is whether they are clean sediments or contaminated sediments, as this greatly affects the manner in which they can be used as beneficial material or if they must be isolated from their surrounding environment. For this resource management strategy, the term *sediment* will mean *clean sediment*, and if the *sediment is contaminated*, the term *contaminated sediment* will be used.

Debris management is also associated with sediment management. Debris may contain sediment, but it is not entirely composed of sediment. Likewise, debris is not trash. Debris consists of fragmented materials that are organic (trees, brush, and other vegetation) and are inorganic (soil, rocks, boulders, and other sediment) that is primarily moved by flood waters. Large woody material is key to sorting material and creating scours and pools. Pools provide an important habitat for juvenile fish, as well as refugia during flood events. Large woody debris also creates turbulences that clean spawning gravels. Debris basins are built in areas subject to debris flows to save lives and protect property. Trash consists of discarded human-made products (e.g., litter) that sometimes comingles with debris. Trash racks are typically placed on critical equipment, such as pump stations, to prevent mechanical failure caused by litter build-up during a flood.

Debris management is critical in flood management and includes the post disaster removal of materials — natural and human-made — generated by a flood and extreme weather events. Debris in these situations can range from boathouses to gravel bars to zoo enclosures.

While debris management is linked, this chapter focuses primarily on sediment management. Sediment management tools are essential for successful integrated water management as the presence or absence of sediment has a significant impact on water and its beneficial uses.

Sediment Management

Sediment, like fresh water, is limited in supply and is a valuable natural resource. Sediment management is critical for the entire watershed, beginning with the headwaters and continuing into the coastal shores and terminal lakes. However, from a human perspective, sediment has a dual nature; it is desirable in some quantities and locations and unwanted in others. Sediment contributes to many positive purposes and is also used for many positive purposes such as beach restoration and renewal of wetlands and other coastal habitats. Sediment is also needed to renew stream habitat. Spawning gravels need replenishment, and fine-grained sediment is needed to maintain, enhance, or restore good quality native riparian vegetation and wetlands. Flood deposits of fine-grained sediment into floodplains are the source of much of California’s richest farmland. Sediment, particularly sediment adjacent to hot springs, has been considered for centuries to hold healing properties. Sediments can also be used for habitat restoration projects, beach nourishment, levee maintenance, and construction material.

The key to effective water-sediment management is to address excessive sediment in watersheds. Potential impacts of excessive sediment generally associated with fine-grained sediments are:

- Clouding water, degrading wildlife habitat, forming barriers to navigation, and reducing storage capacity in reservoirs for flood protection and water conservation.

  Increasing turbidity and suspended sediment concentrations and negatively affecting the ability of surface water to support recreation, drinking water, habitat, etc.
- Affecting sight-feeding predators’ ability to capture prey.
- Clogging gills and filters of fish and aquatic invertebrates, covering and impairing fish spawning substrates, reducing survival of juvenile fish, reducing fishing success, and smothering bottom dwelling plants and animals.
- Physically altering streambed and lakebed habitat.

Other excess sediment issues sometimes include:

- Reducing the hydraulic capacity of stream and flood channels, causing an increase in flood crests and flood damage. Sediment can fill drainage channels, especially along roads, plug culverts and storm drainage systems, and increase the frequency and cost of maintenance.
- Decreasing the useful lifetime of a reservoir by reducing storage capacity. This loss in storage capacity affects the volume of stored water available for municipal supplies and the volume available for floodwater storage.

- Higher maintenance costs and potential problems associated with excess sediment in shipping channels, harbors, and drainage systems and disposing removed sediment. Excess sediment that accumulates in ports, marinas along the coast, working rivers and recreational lakes, affects boating and shipping activity and can lead to demands for dredging to restore or increase depths.

Toxic pollutants, including those from stormwater, may also be adsorbed onto sediments. Another key to effective water-sediment management is to address this contaminated sediment in watersheds. Contaminated sediment has a direct effect on aquatic life. Concentrated pollutants can greatly impair water quality if they are remobilized back into the environment. Potential contamination issues are:

- Direct effects on aquatic life.
- Toxic pollutants from stormwater may also be adsorbed onto sediments. Contaminates in sediments can bioaccumulate or magnify in the food chain and cause problems for aquatic plants, animals, and humans.
- Impaired water bodies.
- Nutrients such as nitrates, phosphorous, potassium, and toxic contaminants, such as trace metals and pesticides, when resent, are associated with fine-grained sediment. In some cases, suspended sediment particles increase bacterial growth, which can concentrate these nutrients.

Management of watershed sediment location and movement can also have positive and negative consequences, as well as large economic and ecological consequences. For example, excess sediment in shipping channels may cost ports millions of dollars in delayed or limited ship access, while in other locations insufficient sediment deposits could result in the loss of valuable coastal wetlands, beaches, recreation, and tourism, which are worth billions of dollars.

Sediment processes are important components of the coastal and riverine systems integral to environmental and economic vitality. Sediment management relies on knowledge about the context of the sediment system and forecasts about the long-range effects of management actions when making local project decisions. A major goal in sediment management is to stabilize and/or restore the watershed for sediment production meaning mimicking natural sediment production, not eliminating it, and thus provides the various ecological and beneficial uses. Watershed stability is determined by performing geomorphic assessments of the waterways within that watershed. Then, for the produced sediment, use this sediment most beneficially throughout the watershed.

Numerous factors including geology, climate, development and population, and the location of littoral cells affect sediment management issues. Littoral cells are self-contained sections, or a compartment, along the coast wherein sand enters (streams, cliff erosion) temporarily resides (beaches), and exits (submarine canyons, offshore shelf). These factors vary significantly throughout the state. For that reason, sediment is best managed on a watershed-littoral cell basis, taking into consideration the sediment source and needs from the top of the watershed to the coast where sediment will ultimately end. Adjacent littoral cells do not typically share sand whereas fine-grained sediments exhibit different behavior along the coast (e.g., turbidity plumes cross over cell boundaries). Regional sediment management recognizes sediment as a valuable resource and supports integrated approaches to achieve balanced and sustainable solutions for sediment related needs.

Management Framework

The Regional Water Quality Control Boards (RWQCB) provide regulatory oversight for transport of course-grained sediment to the coast and management of excessive watershed sediments. The USACE, EPA, State Lands Commission, and San Francisco Bay Conservation Development Commission also have authority for aspects of sediment management and dredging in their respective jurisdictions.

A stream that has excessive erosion, suspended sediments, and/or sedimentation may be determined by a RWQCB to be unable to support its designated beneficial uses and may be listed as impaired under the Section 303(d) of the Federal Clean Water Act. The RWQCBs are working to reduce excessive sediment within streams when it occurs within their regions through the use of total maximum daily load (TMDL) requirements. The *National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle* , shows that sediment is a major water quality problem in the nation's streams.

PLACEHOLDER Box 26-1 [explains beneficial uses from the Water Board's perspective]

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Partnerships have been formed throughout California to manage sediments better in a variety of ways. In San Francisco, the USACE, the EPA, the Regional Water Quality Control Boards, the San Francisco Bay Conservation and Development Commission (BCDC), and the State Lands Commission formed a partnership to address the disposal and beneficial reuse of sediment dredged from the San Francisco Bay. The Long-Term Management Strategy for the Placement of Dredged Sediment in the San Francisco Bay Region (LTMS) reduces in-bay aquatic disposal of sediments in favor of reusing that sediment beneficially in habitat restoration projects, levee maintenance, agricultural enhancement, and construction projects. LTMS emphasizes using sediment as a resource while simultaneously reducing impacts from aquatic disposal in the bay. This program coordinates and manages approximately 110 maintenance dredging projects, regulated by eight state and federal agencies under a common set of goals and policies. The LTMS policies and management practices also enable streamlining the permitting process, including coordinating programmatic consultations with the resource agencies, standardizing testing protocols, and increasing predictability for organizations with permits. There is also a quasi-LTMS process in the Delta.

On a statewide basis, the California Coastal Sediment Management Workgroup (CSMW) was established to develop regional approaches to restore coastal habitats, such as beaches and wetlands, that have been impacted by human-induced alterations to natural sediment transport and deposition through federal, State, and local cooperative efforts. CSMW is comprised of many State, federal, and local interests whose mission is to identify, study, and prioritize regional sediment management needs and opportunities along the coast and provide this information to resource managers and the public.

The CSMW was formed in response to concerns that shore protection and beach nourishment activities were being conducted on a site-specific basis, without regard to regional imbalances that could exacerbate the local problem. The consensus was that a regional approach to coastal sediment management is a key factor in developing strategies to conserve and restore California's coastal beaches and watersheds. The CSMW's main objectives include reducing shoreline erosion and coastal storm damages, restoring and protecting beaches and other coastal environments by reestablishing natural sediment supply from rivers, impoundments and other sources to the coast, and optimizing the use of sediment from ports, harbors, and other opportunistic sources.

The CSMW oversees the development of the California Coastal Sediment Management Plan (SMP) (http://www.dbw.ca.gov/csmw/smp.aspx). The SMP will identify and prioritize regional sediment management (RSM) needs and opportunities along the coast, provide this information to resource managers and the public, and streamline sediment management activities. A series of Coastal RSM Plans (strategies) are being developed for one or more individual littoral cells focusing on issues specific to each region. Tools, documents, and RSM strategies developed to date are available on the CSMW Web site (www.dbw.ca.gov/csmw).

Sediment Management and Flood Management

Sediment management is a key consideration in flood management. Sediment deposition in the channel or floodplain can decrease flood capacity/flood management. Sediment-starved channels can increase velocity, which can increase flooding.

When a river breaks its banks and floods, it leaves behind deposits of sediment. Sediment concerns consist of more than erosion. Overtopping can result in depositions in the channel or in the floodplain, which affect flood management. These depositions can reduce flood capacity. Rivers can also erode their banks and potentially erode levees or flood control structures. These gradually build up to create the floor of floodplains. Conversely, floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, silt, and/or clay, and are often important to aquifers because the water drawn from them is pre-filtered compared to the water in the river.

Geologically ancient floodplains are often represented in the landscape by fluvial terraces. Fluvial processes are the movement of sediment, organic matter, and erosion that deposits on a river bed, and the land forms this creates. Fluvial terraces are old floodplains that remain relatively high above the present floodplain and indicate former courses of a floodplain or stream.

When floodplains are separated from the water source, through levees or other means, the natural process of equilibrium, which elevates the land through sediment deposits, is interrupted. This alters the historic flooding and sediment distribution patterns. In some cases, sediments remain within the restrained channel, settling and reducing the capacity of the channel, and increasing the likelihood of flooding. In many cases, this is avoided by dredging the channel and then mechanically depositing the sediment in desirable locations.

Alluvial fans are another form of flood sediment deposit. Over geologic time, sediment, debris, and water emerge from the mountain front along different courses. Alluvial fans are found where these materials gather speed in narrow passages then emerge into less confined areas where they can change course. A number of factors contribute to the severity of these flows including the degree of steep grades to flatter grades. Sediment, debris, and water spill out in a fan shape, settling out and depositing on its way. The channels on these fans range from shallow to very deep (several meters) with a flow speed that can move boulders that are sometimes taller than a house. These conditions are found in California at mountain fronts, in intermountain basins, and at valley junctions. Alluvial fans are found where sediment loads are high, for example, in arid and semiarid mountain environments, wet and mechanically weak mountains, and environments that are near glaciers.

Historic Context

A combination of both natural and human-made impacts to California waterways has led to today's sediment management challenges and solutions. Historically and prior to California becoming a state, sediment flowed naturally from the mountains into streams, meadows, rivers, lakes, and the ocean. California Native Americans understood the seasonal and climate impacts of waterway flows and drought which impacted levels of sediment. This environment provided a wide variety of flora and fauna that was useful as food and tool manufacturing sources for native people (Theodratus 2009). As Europeans encountered the territories that became California, they altered this landscape by dredging passages of interior waterways for navigation, and captured a reliable water supply for their new settlements.

In addition to alterations to facilitate agrarian settlements, many of California's current sediment management issues also can be traced to historic gold dredge activities in the 1850s. California's Central Valley and Bay-Delta waterways experienced significant alteration caused by billions of cubic yards of sediment and debris sent downstream from hydraulic mining operations. Court action stopped these activities. However, impacts from these activities continue today. Ditches used for mining are still in use for agriculture and public water supply. The channel infilling that occurred in many of the gold bearing streams is still in evidence and many streams, such as the Feather and Yuba rivers, and these are still adjusting their watercourses 150 years later.

Some early reservoirs (Clementine, Englebright, Camp Far West) were initially built to capture the sediment. There are still millions of tons of mining debris remaining on the floodplain. The U.S. Geological Survey has measured the amount of sediment entering the San Francisco Bay from numerous tributary streams and determined the historic changes in sediment yield over the long term. Today, scientists have concluded that much of the hydraulic mining sediments have moved through the Delta and potentially through much of San Francisco Bay. However, multiple institutions, laws, and human settlement patterns created during this era remain, and, ironically, wetlands that were established as a result of the inundation are now undergoing erosion.

Beyond the Delta and Central Valley, impacts from historic and current road building and land management practices continue to contribute to existing problems. Landslides resulting from natural and human processes are a major producer of sediment.

Additional system alterations also occurred as dams and channels were built for both water supply and flood protection. More and more structures changed what had been the natural hydrology, which then altered system stability for sediments. As a result, the normal function of waterways has also been changed to produce sediment, move it through the watershed, with some settling occurring in low areas that are now typically used for farming or urbanization, and ultimately depositing it at the shoreline, replenishing the coastline or terminal lakes. In addition to sediment being trapped in flood control structures, peak velocities during storm events has also been reduced, limiting the ability of the stream to move coarse-grained sediment downstream to the coast.

Many ports and harbors were constructed in the 1940s and 1950s along the coastline without regard to the natural process of sand transport along the coast. This natural transport activity has been interrupted by the entrance channels to the harbors, such that the sand being transported down the coast is deposited instead within the entrance channels. This shoaling results in shallower depths and potentially hazardous conditions within the channel, necessitating the ongoing dredging of the channels to restore function and safety. Beneficial reuse of the dredged material is an opportunity for regional sediment management.

Due to the desire to work, live, and play along the coast, significant development along the shoreline has occurred without consideration of the impacts to such development by natural processes. As a result, much of the shoreline has been armored to reduce erosion at specific locations to protect specific structures. Such armoring has reduced the natural supply of sediment to the beaches from bluff erosion. This causes beaches to become more narrow and there is an associated loss of habitat and access from passive erosion and accelerating erosion of adjacent areas due to wave focusing.

Land use has also altered patterns of natural alluvial fans. As one example, much sediment in Los Angeles County is the result of the naturally erosive mountains. The San Gabriel Mountains are mostly undeveloped because they are within the Angeles National Forest. Other mountain ranges (Santa Monica, Verdugos, Puente Hills) also have large areas of undeveloped land. The basins and valleys below these mountains are large, relatively flat, alluvial plains. The depth of the sediment deposits indicates that a significant portion, and possibly the majority, of the sediment are from the adjacent mountains.

Many Los Angeles County residents/businesses moved into these flat alluvial plains. The original inhabitants, impacted by frequently fluctuating watercourse alignments caused by high amounts of sediment deposition, wanted more stable river/stream alignments for use and recharge. This situation led to the construction of dams, debris basins, channels, and spreading grounds in Los Angeles County to serve agricultural and urban areas. Farms and subdivisions were then located in naturally occurring sediment disposal areas Many of those inhabitants are unaware that they are sitting on still-active alluvial fans.

Management Approach

Understanding the cumulative impacts of all past, present, and proposed human activities in a watershed (and/or littoral cell) is important in predicting the impacts of sediment on surface waters. Sediment management in water bodies typically focuses on addressing three issues:

1. The type and source of sediment.
2. The systems transporting sediment.
3. The location where sediment deposits.

Management actions are tailored to the situation, depending on the location where the management actions will occur and whether the management actions involve a natural environment (rivers, streams, creeks, and floodplains) or a built environment (water control structures, flood levees, dams).

Source Management

Source management is preventing soil loss and adverse sediment flows from land use activities that may, without proper management, cause erosion and excessive sediment movement. Routine source management activities prevent or mitigate excessive sediment introduced into waterways due to recreational use, roads and trails, grazing, farming, forestry, and construction. Excessive flows affecting erosion and sedimentation may also result from land-based events such as extreme weather, fires, high water volumes, wind, and other factors.

Road construction and maintenance in or near streams can also be a source of sediment. Photo 26-1 is a picture of the Caltrans I-5 Antlers Bridge realignment project on Shasta Lake. The photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters (Central Valley Regional Water Quality Control Board 2011).

PLACEHOLDER Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

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Another transportation related source is off-highway vehicle (OHV) use. OHV is a popular form of recreation in California. State, federal, local agencies, and private entities provide recreational areas for this purpose. These OHV recreation areas are required to implement a range of sediment management and stormwater Best Management Practices (BMP) to protect water quality. Unfortunately, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted stormwater. With limited resources, maintaining and policing these areas can be a challenge.

Sedimentation can be a problem in the construction and operation of many mines. Increased potential for erosion and sedimentation at mines are related to mine construction and facility location. Tailings dams, waste rock and spent ore storage piles, leach facilities, or other earthen structures are all potential sources of sedimentation to streams. Road construction, logging, and the clearing of areas for buildings, mills, and process facilities can expose soils and increase the amount of surface runoff that reaches streams and other surface water bodies.

Agencies and Organizations Involved in Source Sediment Management

Many agencies and organizations contribute to sediment source management as land managers, land use planners, advisors, and regulators, and through training, technical and financial assistance, and promotion of good policy. An overview of some of those key entities and their activities are in Table 26-1.

PLACEHOLDER Table 26-1 Agency Roles and Activities in Sediment Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment Transport Management

Sediment, like water, flows downstream and supports both shorelines and habitats at the end of the line. Rivers and streams carry sediment in their flows. There is a range of different particle sizes in the flow. It is common for material of different sizes to move through all areas of the flow for given stream conditions. The sediment can also be in a variety of vertical locations within the flow, depending on the balance between the upwards speed on the particle (drag and lift forces), and the settling speed of the particle.

Sediment, primarily sand, also moves along the coastline as littoral drift. This "river of sand" is driven by wind and waves interacting with the shoreline and its orientation. Sand enters the littoral cell from streams and rivers, moves downcoast picking up additional contributions from eroding bluffs, and leaves the littoral cell when it reaches a submarine canyon. Some sand is also lost to the offshore during large storm events. The sand resides temporarily along the coast as beaches, and fluctuations in the supply/loss of sand to the system will affect beach widths.

PLACEHOLDER Box 26-2 Definitions

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment transport management is the process of introducing or leveraging natural functions that create optimal sediment transport. This involves managing the speed and flow of the sediment conveyance and the natural or built structures to achieve a properly distributed balance of sediment types in the habitat. Properly managed transport of sediments will result in the optimal sediment deposition.

For example, sand bypass structures in flood control channels are starting to be used. Such structures placed into flood channels allow the coarse-grained sediments to be diverted to a settling pond where they can be excavated and used for construction, while the fine-grained sediments are diverted to a wetland where they add to the size of the wetland. More information on this method can be seen at http://www.ocwatersheds.com/Documents/wma/LaderaRanch_HNouri.pdf and http://www.ocwatersheds.com/Documents/wma/Integrated_Mgmt_of_Stormwater_Sediment_and_Pollutants_in_Ladera_Ranch.pdf.

Sand transport management along the coast includes dredging harbor entrance channels that have become clogged with the migrating sands, and transporting the dredged materials to some other location. In some areas, sand traps have been constructed to facilitate such transport prior to the sands entering the harbors. Elsewhere along the coast, retention structures (e.g., groins) have been constructed to slow down the alongshore transport, maintaining beach widths for longer periods of time. If the area upcoast of the groins is not properly filled with sand, beaches downcoast of the groins can experience accelerated erosion.

Sediment Deposition Management

The goal of sediment deposition management is to achieve optimum benefits from sediment deposits and mitigate negative impacts. As noted previously, properly distributed sediment has numerous beneficial outcomes such as:

- Fine-grained sediments supporting existing habitat and adapting to sea level rise.
- Gravel remaining in rivers and streambeds for habitat and riverbed stability.
- Sand sustaining beaches both for recreation and habitat.
- Fine silts and clays introducing nutrient rich materials and nutrient cycling.
- Deposits creating buffers, particularly offshore, that reduce climate change and storm surge impacts. Coastal areas that benefit from sediment can also include offshore mudbelts.

Deposition management also includes techniques to prevent and mitigate the negative aspects of excessive sediment including:

- Siltation creating an impact the capacity of floodways, reservoirs, and water supply systems including dams.
- Siltation creating unsafe shipping and transportation channels and creating an impact on other commercial and recreational navigation.
- Siltation inundating wetlands.
- Deposition filling pools and embed riffles, which reduces stream habitat.

The USACE maintains the primary federal permitting and operational responsibility over waterway and navigational dredging, flood control, and the operation of many dams. The EPA oversees USACE's implementation of its Clean Water Act and Marine Protection, Research, and Sanctuaries Act (MPRSA) responsibilities, as well as establishing water quality criteria and implementing certain TMDLs. Additionally, the U.S. Bureau of Reclamation maintains a significant federal role in maintenance, construction, and even deconstruction of dams.

The California Coastal Commission, Department of Water Resources, the State Lands Commission, State Water Resources Control Boards, and BCDC serve as State counterparts. Additional federal and State resource agencies are responsible for fisheries and recreation.

Dredging and Sediment Extraction

Dredging is an excavation activity or operation usually carried out, at least partially underwater, in shallow water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

Other forms of sediment extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel, and sluicing. Sluicing is a sediment removal method that employs water flow to remove smaller particle sediment (i.e., sands and silts) to remove sediment accumulated in reservoirs. Sluicing is one of the two methods the Los Angeles County Flood Control District has used since the 1930s to remove sediment from its reservoirs.

Extraction methods are often used to maintain the capacity of flood and water supply infrastructure and mine sediment, sand, and gravel for multiple purposes such as commercial construction, levee stabilization, and environmental restoration. Determining how the extracted sediment will be managed involves a variety of factors including environmental acceptability, and technical and economic feasibility.

Dredging is a critical sediment deposition management activity supporting commercial shipping, homeland security, fishing, recreation, and environmental restoration. Detailed descriptions of dredging equipment and dredging processes are available in Engineer Manual (EM) 1110-2-5025 (U.S. Army Corps of Engineers 1983; Houston 1970; Turner 1984).

In San Francisco Bay alone, dredging facilitates a substantial maritime-related economy of more than $7.5 billion annually. By necessity, maritime facilities are located around the margins of a bay system that averages less than 20 feet deep, while modern, deep-draft ships often draw 35 to 50 feet of water or more. In order to sustain this region's diverse navigation-related commercial and recreational activities, extensive dredging — in the range of 2 to 4 million cubic yards (mcy) per year — is necessary to maintain adequate navigation channels and berthing areas. Effective management of the large volumes of dredged material generated throughout this estuary is both a substantial challenge and an opportunity for beneficial reuse. Both are addressed by the Long Term Management Strategy for Dredging (see http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf) and the interagency Dredged Material Management Office. Navigational dredging in Southern California is similarly managed to encourage beneficial reuse wherever possible under the Los Angeles Basin Contaminated Sediment Management Strategy's Master Plan and the interagency Dredged Materials Management Team.

There are some known issues related to dredging and other forms of sediment extraction:

- Dredging and sediment extraction can directly impact water quality, habitat quality, and contaminant distribution. Operations may reduce water quality by introducing turbidity, suspended solids, and other variables that affect the properties of the water such as light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH, and concentrations of trace metals and organic contaminants if they are present in the sediments (see http://www.spn.usace.army.mil/ltms/chapter3.pdf).
- Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion since saline water is heavier than freshwater, potentially causing an impact to freshwater supplies and fisheries (e.g., deepening of the Sacramento and Stockton deep water ship channels in the Delta). Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area), with consequent degradation of groundwater quality in shallow aquifers.
- Sediment removal operations may also reintroduce contaminants into the water system by re-suspending pollutants. Metal and organic chemical contamination is widespread in urban shipping channels due to river runoff and municipal/industrial discharges. Chemical reactions that occur during removal may also change the form of the contaminant. These chemical reactions are determined by complex interactions of environmental factors, and may either enhance or decrease bioavailability, particularly those of metals. At the same time, dredging can aid in overall reduction of pollutants in a water body when contaminated sediments are removed from the system or sequestered in habitat restoration projects.

Many things have been done to address these existing issues. There are pre-dredging and real-time monitoring programs that have been developed to test the quality of sediments to be dredged, and there are alternative disposal sites where different quality sediments can be taken. Time windows for when some dredging can occur have been established to accommodate certain ecological cycles. Upland sediment disposal sites can be designed to mitigate for many contaminants, and extremely contaminated sites can be capped in-place underwater. Evaluation of dredged material for ocean disposal under the Marine Protection, Research, and Sanctuaries Act (MPRSA) relies largely on biological (bioassay) tests. The ocean testing manual, Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual), commonly referred to as the Green Book, provides national guidance for determining the suitability of dredged material for ocean and near-coast disposal. Evaluation of dredged material for inland disposal under the Clean Water Act (CWA) relies on the use of physical, chemical, and/or biological tests to determine acceptability of material to be disposed. The inland testing manual, *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual*, provides national guidance on best available methods.

Beneficial reuse of dredged and extracted sediments can solve what can otherwise be a dilemma of how to dispose of dredged and extracted sediments as a waste by repurposing it in a variety of ways. These can be used to raise subsided lands to allow restoration as an agricultural supplement and to support levees. When this occurs, the economics of disposal may be altered. In particular, the initial cost to the dredger for sediment removal and placement may be increased. For example, reusing the sediment may require different equipment, the transportation distance to the reuse site may be greater than to the traditional disposal site, and the amount of time needed to complete the dredging work may be extended. In addition, sediment is a public trust asset and thus it is subject to State mineral extraction fees and other restrictions. Because public trust lands are held in trust for all citizens of California, they must be used to serve statewide, as opposed to purely local, purposes.

Dam Retrofit and Removal

Dams are an important part of California's water and flood management and will remain so for the foreseeable future. Sediment deposits naturally behind dams and reservoir sediment management includes a range of options including sluicing of sediment, dredging, redesign, retrofit, and removal.

Dam retrofit is an option for deposition management. The Natural Heritage Institute (NHI), a non-governmental and non-profit organization, has been a pioneer in this area. They are investigating the feasibility of re-operating some dams in order to restore a substantial measure of the formerly productive floodplains, wetlands, deltas, and estuaries located downstream in ways that do not significantly reduce — and can sometimes even enhance — the irrigation, power generation, and flood control benefits for which the dams were constructed.

Dam removal is sometimes a result of sediment management, or it creates a need for sediment management. As noted earlier, sediments trapped behind dams or in reservoirs may require periodic sediment removal to maintain function and capacity. However this is sometimes extremely challenging due to the facility's location and the lack of disposal or beneficial reuse opportunities at nearby locations. In recent years, there has been increased interest in dam removal for sediment-related reasons, such as the loss of capacity of the facility to hold water due to accumulated sediment. In other cases, the reasons may be unrelated, such as a need to upgrade hydrogenation or improve a stream fishery. Analysis of dam removal proposals requires significant discussion of sediment deposition management. Management of sediments behind such dams has been an important element of negotiations related to dam decommissioning.

Regional Sediment Management

Regional Sediment Management (RSM) refers to the practice where sediment is managed over an entire region. Managing sediment to benefit a region potentially saves money, allows use of natural processes to solve engineering problems, and improves the environment. RSM as a management method:

- Includes the entire environment from the watershed to the sea.
- Accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, estuaries, and oceans.
- Protects and enhances the nation's natural resources while balancing national security and economic needs.

RSM is an approach for managing projects involving sediment that incorporates many of the principles of integrated watershed resources management, applying them primarily in the context of coastal watersheds. While the initial emphasis of RSM was on sand in coastal systems, the concept has been extended to riverine systems and finer materials to completely address sources and processes important to sediment management. It also supports many of the recommendations identified by interagency working groups for improving dredged material management. Examining RSM implementation through demonstration efforts can provide lessons not only for improved business practices, techniques, and tools necessary for managing resources at regional scales, but also on roles and relationships that are important to integrated water resources management.

This is a growing concept nationwide which also has economic benefits. The USACE has a primer on Regional Sediment Management at http://www.spur.org/files/u35/rsmprimer.pdf.

More information about RSM can be found in the American Society of Civil Engineers written Policy Statement 522, on Regional Sediment Management at http://www.asce.org/Content.aspx?id=8638.

Connections to Other Resource Management Strategies

Many other resource management strategies in *California Water Plan Update 2013* share a connection with sediment management. More information on each of these resource management strategies can be found in these chapters under Volume 3, *Resource Management Strategies, California Water Plan Update 2013.*

- "Agricultural Lands Stewardship," Chapter 21. Agricultural land stewardship directly links to management of erosion and soils protection. Proper management in both private and public land ownership prevents disruptive development patterns and supports sediment aware farming and ranching practices.
- Conveyance. Depending on design, conveyance facilities can either trap, scour, or result in other unnatural distribution of sediments. Sediment overload can significantly reduce system capacity.
- "Ecosystem Restoration," Chapter 22. Native riparian, aquatic, animal, and plant communities are dependent on effective sediment management. These ecosystems are dynamic and are highly productive biological communities given their proximity to water and the presence of fertile soils and nutrients. Many opportunities for improvement in both sediment management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. Sediment management projects that result in protected and restored ecosystems will likely create increased effectiveness, sustainability, and public support.
- "Flood Management," Chapter 4. Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of the floodplain, the depth and composition of soils, and the type and density of vegetation. Sediment transport dynamics can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is also a major component of alluvial fan and debris-flow flooding.
- "Forest Management," Chapter 23. Forestation practices can influence sediment transport from upland streams. Wildfires can reduce surface water infiltration, which can cause additional erosion and debris flooding.

- "Land Use Planning and Management," Chapter 24. The way in which land is used — the type of land use, transportation, and level of use — has a direct relationship to sediment management. One of the most effective ways to reduce unnatural sediment loads is through land use planning that is fully abreast and reflective of applicable sediment and hydrology practices. This includes site design to reduce the introduction of unnatural loads of sediment into waterways.
- "Outreach and Engagement," Chapter 29. Outreach is needed to educate the public regularly on sediment management concerns. Outreach is also needed to educate the public on the natural beneficial functions of sediment.
- "Pollution Prevention," Chapter 18. Well-designed pollution prevention efforts improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion, and sedimentation of streams.
- "Municipal Recycled Water," Chapter 12. Soil structure can be altered by the composition of water that interacts with it, particularly sodium-loaded soil that may be found in many soils that have been irrigated with some recycled waters. Soil organic matter increases both the water-holding capacity of mineral soils considerably and the cation-exchange capacity. In soil science, cation-exchange capacity (CEC) is the number of positive charges that a soil can contain. It is usually described as the amount of equivalents necessary to fill the soil capacity. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. Some studies about infiltration rates between local well water (slightly calcic) and recycled water used for irrigation on a silty clay loam have found significant differences and reduced infiltration for the soils subject to the recycled water.
- "Urban Stormwater Runoff Management," Chapter 20. Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways and the timing and extent of sediment introduction into the system. The impervious surfaces increase runoff volumes and velocities, resulting in stream bank erosion and potential unnatural sediment distribution downstream. Watershed approaches to urban runoff management attempt to manage sediments to mitigate negative impacts and support beneficial uses in a manner that mimics the natural hydrologic cycle.
- Surface Storage. Similar to conveyance, sediments may be trapped behind infrastructure or otherwise unnaturally distributed. This results in a loss of system capacity.
- "Water and Culture," Chapter 30. Sediment is used in traditional ceremonies and considered to contain healing, and in some cultures, it has spiritual properties. Mud structures are important to native peoples and for some, mud has ties to the creation story. See *Tribal Water Stories* at http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.
- "Water-Dependent Recreation," Chapter 31. Water and land-based recreational activities can contribute to unnatural erosion and sediment production. Conversely, high sediment loads can negatively impact recreation, particularly boating, fishing, and swimming. Adequate supply of sand and gravel sediments is essential for many beach recreational activities.
- "Watershed Management," Chapter 27. Watersheds are an appropriate organizing unit for sediment management. Restoring, sustaining, and enhancing watershed functions are goals of sediment management in the context of integrated watershed management.

Potential Benefits

The ultimate benefits of sediment management relate to preventing the negative results of too little or too much sediment and repurposing sediment for beneficial uses. As noted above, benefits associated with reducing impacts just to navigation and commerce may achieve cost savings of millions. A similar statement can be made about the management of sediment that accumulates at reservoirs and debris basins and is prevented from flooding communities downstream.

Source Sediment Management

An average of 1.3 billion tons of soil per year are lost from agricultural lands in just the U.S. due to erosion (McCauley and Jones 2005) (http://landresources.montana.edu/SWM/PDF/Final_proof_SW3.pdf). Considering that soil formation rates are estimated to be only 10–25% of these erosion rates (Jenny 1980), loss and movement of soil by erosion is a major challenge for today's farmers and land managers. Soil erosion over decades can have detrimental effects on productivity and soil quality because the majority of soil nutrients and soil organic matter (SOM) are stored in the topsoil, which is the soil layer most affected by erosion. For these reasons and more, sediment management for soil sustainability has numerous multiple benefits far exceeding the scope of the California Water Plan.

In the case of urban land management, use of low-impact development and other sediment management practices can reduce negative impacts of stormwater runoff, by maintaining the natural production of sediment and improving permeability of drainage areas. Land use goals for sediment may also improve flood management. By improving the flood system hydrology, sediment management results in improved safety and environmental and economic outcomes.

Coastal Sediment Management

Sediment in the coastal waterways can furnish material needed to replenish the beaches and marshes along the coastal areas. If the sediment is removed from navigation channels or harbors, the extracted material can be used for beach or marsh nourishment, construction purposes such as highway sub-base material, and flood control levees.

Widening the shoreline, either via beach nourishment or marsh restoration, improves storm surge and flood protection. The dollar value of this improved protection is nearly incalculable, not just for those who own coastal structures, but for the extraordinary number of infrastructure improvements that support the state, including power generation, major transportation assets, water systems, and the dollar value of the recreation and tourism industries that are large part of the state's economy. Restoring eroded coastlines also improves habitat for coastal biota and improves access safety to the shorelines.

Fisheries

In terms of water management, natural amounts of coarse-grained sediment (sand and gravel) in the stream and river system has many beneficial uses. It can serve in the inland waterways as a substrate for fish spawning areas. Enhancing the sustainability of the fishery benefits not only the state's fishing industry, but is also a water supply benefit as a declining fishery may lead to reductions of water exports or use of some water rights.

Beneficial Uses for Extracted Sediment

Extracted sediment is a manageable, valuable soil resource with beneficial uses of such importance that it should be incorporated into project plans and goals at the project's inception to the maximum extent possible. For example, extracted sediment can benefit:

- Habitat restoration/enhancement (wetland, source, island, and aquatic sites including use by fish, wildlife, waterfowl, and other birds).
- Beach nourishment.
- Aquaculture.
- Parks and recreation (commercial and noncommercial).
- Agriculture, forestry, and horticulture.
- Strip mine reclamation and landfill cover for solid waste management.
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms.).
- Construction and industrial use(including port development, airports, urban, and residential.
- Material transfer for fill, dikes, levees, parking lots, and roads.
- Multiple purposes (i.e., combinations of the above).
- Coastal Access.
- Storm Surge Protection.

The applicability of uses is subject to the demand for materials. An issue or barrier might be matching disposal to uses. A detailed discussion about various beneficial uses for extracted material is at http://water.epa.gov/type/oceb/ndt/beneficial_use.cfm and other related sources.

System Capacity and Materials Use

There are multiple benefits of managing the sediment that accumulates at reservoirs and debris basins. If sediment that accumulates in reservoirs is not removed, storage capacity is reduced. As an example, flood control reservoirs which have a water conservation purpose (and most of them do), water captured in the reservoirs maybe used to recharge local groundwater aquifers. If sediment is not removed or is passed through, then the storage capacity for water or hydropower is reduced. If sediment is not removed from reservoirs and debris basins, the ability to provide flood risk management, water supply, or hydropower is diminished.

Special Situations

The battle to maintain Lake Tahoe as a pristine and visual jewel is an unusual sediment case study. The sediment of concern is very fine-grained sediment (less than 20 microns) that affects the clarity and people's aesthetic enjoyment of Lake Tahoe. In this case, the problem may be unique and the extensive costs of basin-wide improvements would not translate to other situations. Even so, there have been many new and innovative best practices for sediment management in the basin and these can translate to other programs. Additionally the benefits of the investment have been equally evaluated and are considered to be of national interest.

Potential Costs

[PLACEHOLDER FROM WATER BOARDS - Include Lake Tahoe MS information on investments.]

Many agencies and organizations engage in sediment management activities. The cost of implementing sediment management to achieve water benefits varies widely depending on the sector and purpose of the management. When looking at the overall costs of sediment management, managers should consider and quantify the beneficial uses of the sediment and the ecosystem services, flood protection, storm surge protection, and water quality improvements associated with the benefits as a balance in comparison to the up-front financial investments. While the financial investment is often a one-time cost, the benefits are regularly long term, such as creating a wetland that provides habitat and water quality improvements in perpetuity.

A few sample investments in sediment management include:

Natural Resources Conservation Service (NRCS). From 2007 to 2012, the NRCS obligated more than $91 million in California for conservation practices to address soil erosion and sedimentation on agricultural land. These practices are recommended to reduce erosion, prevent the transport of sediment, or trap sediment before it leaves the farm or field.

USDA Forest Service. Overall, watershed restoration project costs on national forests are close to $2,000/acre, and most of these projects have the benefits of reducing erosion and sediment transport. Meadow restoration using the pond and plug approach is about $1,000/acre. Road decommissioning costs about $16/cubic yard of sediment (reduction in potential erosion).

Los Angeles County Flood Control District (LAFCD). Based on the alternatives included in the LACFCD's Draft Sediment Management Strategic Plan (April 2012), the cost to manage the Strategic Plan's 67.5-mcy planning quantity could be as much as $1.2 billion over the 20-year planning period, 2012 to 2032.

U.S. Bureau of Reclamation (USBR) and U.S. Bureau of Land Management (BLM). Gravels are added to Northern California rivers to aid in the anadromous salmon run each year. The amount of gravels added depends on the budget allocated each year. Such gravel additions are occurring in the upper Sacramento River area (i.e., Clear Creek), and in other rivers such as the American River, Yuba River, and Stanislaus River. The costs per ton of gravel added depends upon such factors as the method of placement, tonnage of gravel placed, and how the gravel is placed (e.g., dump trucks dumping gravel directly into river, lateral berms laid alongside the streambed at low water, or sluicing a mix of water and gravel directly into the river). Typical tonnages added may vary from 5,000 to 10,000 tons and more per application. Also, the U.S. National Fisheries Service specifies the amount of cleaning (washing) that has to be done to the gravels prior to application, and the grain size distribution of the gravels, which adds to the cost.

Major Implementation Issues

The issues for implementing sediment management are similar to those experienced by related resource management strategies including:

- The need to balance environmental impacts, social impacts, feasibility, and cost.
- Availability and affordability of land.
- Different stakeholders have different needs and different understandings of the need to manage sediment.

- Local managers implementing site-specific solutions without consideration of the regional backdrop and how regional processes affect the local conditions.
- Stakeholders and regulators lack a complete understanding of the different natural regional sediment regimes and attempt to address issues on a statewide basis.
- Urbanization and other structural limitations may preclude introduction of natural regimes.
- Supply/demand regarding extracted sediment in terms of quantity and timing, sediment type, and use. Beneficial use is contingent or recipients for managed sediment.
- Conflicting federal, State, and local regulations, agency missions, and regulators' unwillingness to compromise navigate these conflicts for the good of a region.
- Significant resistance by some local interests concerned with siting and transfer of impacts. Lack of advocacy to counter negative attitudes, e.g., "don't see, don't care."
- Budget constraints, including the need to find funding source to pay for the incremental costs of RSM.

Sustainability issues facing the three management approaches — sediment source management, sediment transport management, and sediment disposition management — follow.

Sediment Source Management

Lack of Techniques for Coarse-Grained Sediments Management

There is a desire for the coarse-grained fraction of the natural supply of sediments (sand and gravel), but not the fine-grained sediments (silts and clays) from the watershed to enter the streams and rivers so they can replenish these sediments in fish spawning areas, and also move toward the ocean thereby replenishing the sand along the coastal beaches. Research is needed in this area because not many techniques currently exist for coarse-sediment bypassing in inland watersheds. One project in the Bay Area, Flood Control 2.0, recently funded by the EPA Water Quality Improvement grant program, is examining this question. The project will be underway during the next four years and will examine the coarse-grain load in Bay Area flood channels, characterize the channel configurations and constraints, and then identify ways to move coarse-grain sediment through the channels to the shoreline or to develop bypass areas where the sediment is diverted into habitat areas where it is much needed.

In particular, efforts must be made to keep coarse-grained sediments available and clean in fish spawning rivers and streams. Erosion in unstable watersheds brings fine-grained sediments into the channels which may settle and cover the coarse-grained sediments needed for spawning, thus eliminating them from use in the spawning process. This web site, published by Joseph M. Wheaton, describes these needs: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.

Barriers to Supplying Coarse-Grained Sediments to the Coastal Beaches

Many of the beaches along the coastline are receding because their natural supply of coarse-grained sediments from inland rivers has been stopped by dams, extracted for use, deposited on impermeable pavements, coastal armoring, in-stream sand and gravel mining, stormwater controls, changes to the ground surface, and other land use practices.

Instream sand and gravel mining removes a resource that downstream environments need. This situation is anticipated to become worse and accelerate with sea level rise. As noted above, the CSMW is working toward this effort, but challenges remain as agencies aim to work collaboratively, identify the necessary funding, and overcome the traditional jurisdictional conflicts that create misalignment of policy and regulation. Current Corps policy for placement of dredge materials is the lowest-cost alternative which is not always where it could be used best. Sediments can also be used to restore the template of flood protection and in some cases, operations can be moved out of the stream or a mitigation fee can be imposed.

Along the coast, beach nourishment has usually been undertaken by combining the USACE's or other dredgers' maintenance dredging of sandy areas and pumping it or placing adjacent to or directly on the shoreline for distribution either via wave action or by mechanical means. This practice has been well received, however funding remains minimal. Even with these successes, a challenge to beach replenishment occurs when material must be transported over land through beach neighborhoods in order to get to the beaches. In some California locations, sandy beaches, primarily used for recreation, are human-made and require continual replenishment, maintenance, and support.

Cost Allocation

The issue of whose budget pays is a major barrier to reuse of any kind. Often reuse is not only environmentally beneficial, but also presents the optimal use of society's funds. Even then, if the dredging budget will not pay for any increase in placement costs compared to disposal, and if the reuse site will not share some of the costs for receiving otherwise free material from the dredging project, the reuse does not occur. A USACE publication addresses this problem, which is available at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/2009_02_27_oceans_ndt_publications_2007_fed_standard.pdf.

Additionally, current USACE policy for placement of dredged material requires the lowest cost alternative which typically means transport to the location (e.g., beach) closest to the dredge area. Lack of broader policy discussion of this general issue is a lost opportunity to recommend to the Legislature to do a number of things. For example, the Legislature should encourage congressional action to revise how the Harbor Maintenance Trust Fund is distributed and to continue support or even increase funding to entities such as the Coastal Conservancy to share costs with USACE for dredging projects. Cost-benefit ratio for dredge disposal incremental (NED).

Controlling Excessive Sediment from Entering Eutrophic Waterways

Eutrophic waterways typically have a lot of minerals and organic nutrients that are used by plants and algae. They often appear dark and have poor water quality. This occurs when certain nutrients, such as phosphorus, are absorbed on fine-grained sediments and carried into the waterways and lakes. These nutrients can cause algal blooms to be out of control in a lake which then creates a lack of oxygen resulting in fish kills. The sediments also result in a reduction of light and clarity in lakes, thereby harming the food chain and also reducing the aesthetic quality of the lake. Controlling these conditions is challenging and failing to do so is especially harmful to Lake Tahoe.

Implementation of Regional Sediment Management

There are obstacles to the practical implementation of RSM. RSM requires a long-term, multi-year watershed view for planning. Yet, it may be difficult for stakeholders and regulatory agencies to adopt long-term views and without the necessary scale. Federal, State, and local regulations are sometimes in conflict with each other. Successful RSM requires compromises from everyone. Regulators often do not offer a compromise due to statutory requirements, not recognizing others' jurisdiction, and fear of exposure to third party lawsuits. Additional challenges for RSM are finding re-use projects/activities that occur at the same time that the sediment needs to be removed, long distances between potential users and the sediment source, and opposition from inhabitants/stakeholders. CSMEs Costal RSM Plan program aims to address many of these issues by providing a cogent, strategic methodology to address sediment imbalance issues within the specified region using RSM.

Limited Options Due to Other System Requirements

In some cases, the optimum sediment management approach may be precluded due to other system requirements or previously implemented decisions and goals.

As an example, a major shift in land use and population patterns may not be feasible. On a specific project level, large amounts of sediment already accumulated behind reservoirs prohibit the immediate implementation of a different approach to sediment management (e.g., a reservoir may need to be cleaned out to its original condition before a sediment flow-through approach can be implemented).

Also important is the instream sand and gravel mining industry, which, according to some authors (e.g., Magoon) may represent the largest source of downstream loss, but is also providing important benefits to the local economy and source materials for multiple critical uses.

Sediment Transport Management

The discipline of sediment transport management is emerging. Much remains to be learned about the best ways to manage for instream sediment quality objectives to prevent aquatic organisms from being smothered by sediment while also providing sediment for downstream processes and needs.

Lack of Monitoring on Stable (Reference) Sediment Conditions in Watersheds

Altered channels have changed natural hydrogeomorphology and natural sediment processes. There is a benefit in achieving and maintaining watersheds in a stable condition as it relates to the generation and transport of sediments from the land surface to the surface streams. This requires understanding (assisted by geomorphic assessments on channels) and monitoring to determine when watersheds are stable or unstable. Management without these tools causes stream channels to degrade in their geomorphic form and they will not support the native aquatic biological habitat. This affects domestic water supplies (filtration). Unstable sediment conditions may also result in disruption of flood control structures.

Achieving Broad Support for Establishing and Implementing Biological Objectives in Streams

The State Water Resources Control Board is establishing biological objectives, which will include those for suspended sediment as well as deposited sediments (see http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml). Excessive sediment in streams, as well as lack of natural sediment loads, can be detrimental to the aquatic life. Achieving broad support for establishing and implementing biological objectives is sometimes met with resistance.

Sediment Deposition Management

Sediment impacts through turbidity, dredging, or burial are also of concern in the coastal environment. Dredging has the potential to destroy habitat and biota currently residing in that habitat, while placement of sands has the potential to bury biota at the placement area or downcast from it. Both of these activities have the potential to create turbid conditions that if are not abutted, could create adverse conditions for filter feeders, visual predators, and photosynthesis. The CSMW's Biological Impacts Analysis and Resource Protection Guidelines discusses these potential impacts in detail, as well as recommending methodologies to minimize such impacts.

Securing Disposal/Placement Locations

Finding disposal locations has become increasingly difficult and expensive due to development of nearby land, regulatory constraints/requirements, or opposition from those adjacent or along the haul routes to the deposition sites.

Another challenge to disposing of/reusing dredged sediment on dry land is dewatering the sediment. Due to the high content of water if the project is hydraulically dredged, the dewatering areas need to be quite large and a region may not have sufficient space available.

When dredged material is placed at an upland dewatering or stockpile site, often future beneficial uses are not known until a particular reuse is proposed and the Regional Water Quality Control Boards analyze the sediment quality data that was collected during dredging. This is because sediment that may be chemically suitable (considered to be “clean enough”) for one kind of reuse may not be suitable for other kinds of reuse. Often this results in delays for projects wanting to reuse the sediment, and can also constrain the emptying and use of the storage sites for future projects.

Handling Contaminated Sediments

Management of contaminated sediments may be challenging. There are limited resources for cleaning of the sediments and disposal of containments taken from contaminated sediments. The USACE has a National Center of Expertise for handing contaminated sediments at http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

Contaminated Sediment Management

The potential for contamination is a consideration whenever dealing with sediments, whether these are in upper watersheds or in ports and harbors. When a project or a watershed has to contend with contaminated sediment, special considerations need to be applied. Even contaminated sediment can often be reused, but a more limited set of potential uses for that sediment may be available.

Reuse Challenges

Appropriate reuse is sometimes cost-prohibitive. Challenges to using sediment for beneficial uses include finding beneficial use projects that coincide with the timing of sediment removal, long distances between the sediment removal site and the beneficial use site, offloading equipment needs, encountering regulatory obstacles, and encountering steep disposal fees at the beneficial use site.

Regulatory Requirements

Regulatory and management frameworks involving sediment typically are designed to support specific uses. As a result, they involve multiple agencies and jurisdictions that are not necessarily accommodating of the complexities of managing all the aspects of sediment sources, transport, and deposition. As a result, sediment-related projects and/or multiple benefit projects may not be feasible due to timing, costs, and conflicts related to the desired deposition of the sediment. Regionally, the LTMS program previously described provides a cooperative framework for testing, permitting, and beneficial reuse projects. The LA-CSTF is a similar interagency regulatory group. Significant effort and energy is required to maintain such cooperative and collaborative efforts when dealing with dredging and beneficial reuse projects. CSMW also functions as a clearinghouse for member agencies to identify sediment-related activities of interest to other agencies.

Data Availability

A number of issues related to integrated management and better planning and coordination could be improved with better data availability. For example:

- Better planning and decision-making could occur with coordinated mapping efforts to allow agencies to better consider upstream and downstream impacts prior to decision-making.
- Ongoing monitoring would allow better adaptive management and an evaluation of management methods being used.
- Improved forecasting and modeling would support long-term and strategic planning.
- Development of sand and sediment budgets would assist agencies in planning and reduce regulatory conflicts.

Data challenges can be addressed. For example, CSMW maintains a Web site designed to make as much information as possible to costal sediment managers. In addition, there are many Web sites that are devoted to specific topics that CSME has been involved with since 2003. These range from a topical library containing links to relevant reports to a searchable database of references. A spatial database containing numerous data layers is at http://www.dbw.ca.gov/CSMW/default.aspx.

Sediment and Climate Change

Climate change is already occurring and it is projected to continue to alter temperature and hydrology patterns in the state. Climate change studies project an increased frequency of extreme weather, higher temperatures, larger and more frequent wildfires, longer droughts, and more precipitation falling in the form of rain than snow. These changes will bring shifts in vegetative species, heighten soil exposure, and will cause flooding to already vulnerable lands and coastlines, adding a heavy mix of sediment and debris to stormwaters. Coupled with sea level rise and surge, which increases coastal erosion (e.g., more than just beach erosion, and coastal flooding, climate change will amplify the already difficult task of sediment management. Drought and climate change alter permeability and other physical characteristics of sediment. Increased carbon dioxide levels may influence soil chemistry.

Adaptation

Adaptation will necessitate projecting where excessive sediments will source and accumulate, and it is also necessary to build controls that will allow for effective management of those sediments. With climate change expected to bring wetter winter and drier summers, erosion will become an even greater threat to California lands and sediment management. Several adaptation strategies may provide benefits in light of climate change.

In some places, floodplain restoration is feasible. This tactic allows for natural deposits of beneficial sediment and serves dual purposes of managing sediment and replenishing soil. Excess, clean sediment can be used beneficially on eroding beaches and agricultural lands, augmenting natural processes. The Coastal Commission is also funding pilot projects for growing wetlands to protect against surge.

Managed retreat is also a tactic that can be used to manage impacts associated with changing beach width caused by climate change.

Warmer temperatures and higher levels of CO_2 may, in some cases, lead to increased vegetation. Vegetation can minimize runoff and lessen erosion, preventing sediments from entering waterways. Effective management of landscapes including planting heat- and drought-tolerant native vegetation around waterways will minimize sediment loads.

Mitigation

Sediment management is a continuous process that can result in high greenhouse gas (GHG) emissions. Dredging and channel clearing is necessary to ensure adequate capacity for flood protection, water supply, and navigation, but is a constant source of GHG emissions from fossil fuel-powered equipment. Ports in some areas have begun to convert to shoreside electric power that could be sourced to renewable energy as more dredges use electric power, but this will take a major industry effort to convert to a different system. Additional analysis should be undertaken to fully recognize the value of beneficially reusing dredged sediment in habitat projects, and the carbon sequestration capabilities of marshes and riparian habitats. Once these analyses are completed, projects can evaluate whether the GHG created by dredging are fully offset by the beneficial use project.

Recommendations to Facilitate Sediment Management

New recommendations for sediment management may increase costs and/or the amount of time needed to obtain permits. All new sediment recommendations should be strongly evaluated to determine to what extent they could inhibit important water/flood projects and activities. If impacts may occur, some form of mitigation for these effects should be included when implementing any given recommendation.

Policy and Regulatory Reconciliation

1. The State and USACE should convene a stakeholder working group that includes flood protection and water supply entities to recommend methods to overcome sediment management regulatory conflict and encourage long-term thinking, including the issuing of permits that match the time horizon for any established sediment management plan. The stakeholder working group should consult and build upon the successes of the CSMW, because they have tackled many of the issues in a coastal setting that will be encountered by those seeking to implement RSM in inland areas.

2. The USACE, Natural Resources Agency, California Environmental Protection Agency, Department of Finance, Governor's Office of Planning and Research, and the California Water Commission should convene a task force or stakeholder working group to recommend methods for sediment management cost allocation. Often reuse is not only environmentally beneficial, but also presents the optimal use of funds.
   A. The stakeholder group should also evaluate needs for outreach and education on sediment management and offer recommendations for next steps to address those needs.
   B. Specific focus should be given to cover the incremental costs of RSM.

Sediment Source Management

3. The Governor's Office of Planning and Research should develop model general plan guidelines that support optimum sediment source management.
4. Federal, tribal, State, regional and local agencies and stakeholders should support and participate in Regional Sediment Management for those sediments which must be dredged to keep the waterways and other facilities open to navigation or to support flood control efforts. Also, there should be support of those efforts to use that sediment beneficially within regions. One possible use of the sediment is levee construction that can direct the floodwater to the most desirable location.
5. The State Lands Commission and other responsible agencies should scrutinize instream and beach Sediment Mining Permits. The Commission should evaluate impacts of sediment-mining permits on a case-by-case basis, which allow the removal of coarse-grained material directly from stream beds or from coastal beaches. While such permits may be satisfactory in some instances, in other instances such permits reduce the sediment needed for fish spawning beds and for beach replenishment.
6. The State should implement the requirements recommended by the California Association of Storm Water Quality Agencies (CASQA) for stormwater discharge control programs associated with sediment management which
   A. Are technically and economically feasible.
   B. Provide significant environmental benefits and protect the water resources.
   C. Promote the advancement of stormwater management technology.
   D. Are compliant with State and federal laws, regulations, and policies. Reducing or controlling stormwater discharges keeps watershed and industrial pollutants from running into the waterways, thereby improving water quality.
7. The Regional Water Quality Control Boards should work with stakeholders to secure broader support of sediment water quality requirement efforts and promote development of stakeholder-based implementation plans to address excessive sediment problems.

Sediment Transport Management

8. The State should support research and design of fine-grained and coarse-grained sediment bypass structures. This will allow the coarse-grained sediment to be separated and either enter the streams and serve its many beneficial uses there, such as for fish spawning grounds and the restoration of coastal beaches, or be trapped in detention ponds where it can be excavated and used beneficially. The fine-grained sediment will be separated and can be used for wetland establishment or other uses. The separation and removal of fine-grained sediment with their attached nutrients can help improve the water quality in lakes having excessive eutrophication.

This work will need to account for water quality requirements and other interests, such as fishing and recreation.

9. The State should encourage the use of remote sensing as a tool for sediment transport management.
10. The State should support the use of watershed mathematical models, when the occasion demands, which can track sediment from source to transport in the streams. Such models (such as SWAT, HEC-HMS, and HSPF) need adequate calibration and validation, but once calibration is done, these models can help to manage the sediments throughout the watershed. The watershed model can also predict the concentrations of other water quality substances in the water.
11. The Natural Resources Agency and California Environmental Protection Agency should implement, as much as possible, an integrated approach to achieve the maintenance of stable watersheds. A stable watershed is one where sediment yield mimics the natural sediment production that would occur in the absence of anthropogenic conditions. If the watershed is not stable, assist in efforts to make it so.

Sediment Deposition Management

12. Where feasible, the State in cooperation with the local sediment management agencies should determine the Sediment Yields of Watersheds when downstream sediment problems are becoming an issue. This type of monitoring may not be feasible in undeveloped, highly-erosive mountain areas. These yields (such as in tons/square mile/year) can be determined at monitoring sites, which have matching pairs of suspended sediment concentrations and instantaneous flow rate measurements. Knowing the sediment yields will help to manage extraction and dredging budgets for the navigation channels and other non-navigation facilities.
13. The Regional Water Quality Control Boards in cooperation with the local sediment management agencies should expand use of regionally-based sediment screening criteria so that agencies could know sooner what the use of the dredged material could be and plan accordingly. Establish potential uses of dredged material, depending upon its quality, in advance. The upland sites receiving dredged material can then be emptied sooner and become available for additional dredged material. This will assist in maintaining the shipping channel in operational condition.
14. The State Lands Commission and DWR should prepare sand budgets for each watershed when downstream sand availability issues are occurring. Comparisons of these sand budgets over time for each watershed will tell of the effect of source Best Management Practices in affecting sand transport, will be of use in determining how well sand is moving toward the coastal beaches, will allow comparison of sand generation in the watershed to that removed by in-stream sand removal permits, and will tell which watersheds are the best in generating sand. These sand budgets should include the sand budgets developed for coastal areas, including the regional sediment budget studies conducted by UCSC for CSMW.
15. All affected jurisdictions should work with or through the CSMW, because it is preparing coastal RSM plans for most of the littoral cells along the coast.
16. The State should support and provide incentives for expanding successful interagency models to cover dredging projects throughout the state. Identifying beneficial reuse opportunities that support RSM goals should be a key objective of the State’s involvement.
17. The State should develop a funding source to encourage and support beneficial reuse projects, specifically those that enhance, restore, or support habitat including beach nourishment and

wetland restoration projects. State funding can be partnered with federal and private funds to support these efforts.

18. The State may also consider ways to encourage beneficial reuse of sediment without State funding. Specific ideas include providing a tax credit or mitigation credit when sediment is reused beneficially rather than treated as a waste product.
19. The State should enable funding for special districts and local governments to undertake sediment management actions. This could include the ability to levy taxes for sediment management, similar to infrastructure districts.
20. For sediment removal projects from facilities that capture sediment from undeveloped watersheds (e.g., some dams and debris basins), State agencies should allow pre-testing to facilitate deposition of sediment at solid waste landfills, inert landfills, and other potential deposition sites, which otherwise may require testing and affect beneficial use of sediment, especially in emergency situations.

Data Acquisition and Management

21. Federal and State governments should support development of guidelines to identify when geomorphic assessments of streams for watershed stability are appropriate to prevent undue delays in processing permits and ensure that studies are scaled to project size.
22. The Federal and State governments should support sediment and flow monitoring programs of others if needed to determine the sediment yields from a watershed and sediment budgets for downstream areas. They should also establish monitoring protocols that produce scientifically-defendable data of comparable quality throughout the state. Such monitoring will add to the water quality data base of the waterway.
23. The Federal and State governments should support modeling and monitoring for sediment dynamics in estuarine and near-shore (littoral cell) environments when understanding estuarine and near-shore sediment transport issues is key to adaptive management, infrastructure protection, and habitat restoration.
24. The State should expand efforts for a sediment data exchange and cooperate with others who may be obtaining sediment data in a watershed so that a common database is used that is accessible to all users. Stakeholders should be convened to establish data needs and requirements. CSMW has developed a GIS database and associated web viewer, and is working with the Ocean Protection Council to incorporate their spatial data into the State Geoportal, currently under development. The State Geoportal is envisioned as a one-stop location for most of California agencies' geospatial database.
25. All responsible agencies should utilize a common GIS mapping framework and use GIS to overlay maps relating sources of excessive sediment production in watersheds with areas having sediment problems in the stream in those watersheds.

PLACEHOLDER Box 26-3 Case Study: Sediment Management Related to Recreational Use

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

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Table 26-1 Agency Roles and Activities in Sediment Management

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Federal	US Department of Agriculture (USDA) Forest Service Natural Resources Conservation Service) Dept. of Interior (DOI) Bureau of Land Management US Geological Survey Park Service Defense USACE	Land Managers, Advisors	Support California land management practices that incorporate erosion control and sediment management. Landscape Conservation Cooperatives
Federal	Dept. of Interior (DOI) US Fish and Wildlife Service Dept. of Commerce NOAA US EPA USACE	Regulators Advisors	Oversight for Dredging, fisheries and TMDL issues
Tribal	Tribal Governments	Land Managers, Planners	Plan and manage for sediment management considerations.
State	CalFIRE Board of Forestry and Fire Protection (BOF) State Lands Commission State Parks Fish & Wildlife	Land Managers Advisors Planners Regulators	Promotion of sediment management through best forest management practices. For over 20 years a group of advisors called the Monitoring Study Group (MSG) has, and continues, to: (1) develop a long-term program testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to the California Department of Forestry and Fire Protection (CAL FIRE) in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE funded monitoring efforts designed to ascertain if forest practice rules, reducing unnatural sediment loads and protecting beneficial uses of water are being implemented and are effective.
State	Department of Food and Agriculture Department of Conservation Fish and Wildlife The University of California Extension Farm Advisors	Advisors Grant Administrators Training & technical Assistance	Provide significant leadership in source sediment management through the development of Best Management Practices (BMPs)

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
State	Water Boards	Regulators Training & technical Assistance	Protect water quality through the issuance of regulations and permits which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares and construction activities. Permits require the implementation of best management practices (BMPs) at constructions sites, outreach and education to residents, and consideration of the principles of low impact development for redevelopment and new development sites. Non-point source (NPS) pollution can include sediment or pollutants carried by sediment. NPS pollution is divided into the following six categories: (1) agriculture; (2) forestry; (3) urban areas; (4) marinas and recreational boating; (5) hydromodification activities; and (6) wetlands, riparian areas, and vegetated treatment systems. The Water Boards administers grant funding to develop and implement management practices to address NPS pollution such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).
Regional	Sierra Nevada Conservancy	Planning Financial Assistance Training & technical Assistance	Promotion of land use practices that support optimum source sediment management
Regional	Tahoe Regional Planning Agency	Planning Regulation	Promotion of land use practices that support optimum source sediment management
Local	Local Governments, Districts, Water Agencies, Reclamation Districts and Planning Commissions	Planning Regulation	Promotion of land use practices that support optimum source sediment management. Some local governments (city and county) support Low Impact Development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, that address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios. Local governments may also be involved in flood protection and water supply. (http://www.epa.gov/owow/NPS/lidnatl.pdf, http://www.epa.gov/region1/topics/water/lid.html, http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf, and http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf & http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Local	Cities Counties JPA's Commission's	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
Local	Resource Conservation Districts	Planning, technical and financial assistance	Resource Conservation Districts (RCDs) implement projects improving sediment management on public and private lands and educate landowners and the public about resource conservation. They work together to conduct: • Watershed planning and management. • Water conservation. • Water quality protection and enhancement. • Agricultural land conservation. • Soil and water management on non-agricultural lands. • Wildlife habitat enhancement. • Wetland conservation. • Recreational land restoration. • Irrigation management. • Conservation education. • Forest stewardship. • Urban resource conservation.
NGO	California and local Farm Bureaus California Rangeland Trust TNC	Advisors Advocates Training & technical Assistance	Information development and dissemination, policy advocacy Land Holding Services
NGO	California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical Assistance	Assists the Water Boards and municipalities throughout the state of California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of Best Management Practices (BMP) Handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including New Development and Redevelopment, Construction Activities, Industrial and Commercial Activities, and Municipal Activities (CASQA Web sites: http://www.casqa.org/ and http://www.cabmphandbooks.com).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Private Interests and Land Managers	PG&E, Southern California Edison and other major private utilities with large land and water holdings and infrastructure. Tejon Ranch. Irvine Ranch, etc. Timber & Rail companies (e.g. Sierra Pacific, Catellus Corporation, a successor to the Southern Pacific Land Company and affiliated with Santa Fe Pacific) Agriculture	Land Management	Pacific Forest and Watershed Lands Stewardship Council (PG&E) Irvine Ranch Conservancy Tejon Ranch Conservation and Land Use Agreement

Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[photo to come]

Box 26-1 Debris and Sediment

The Sediment Resource Management Strategy (RMS) relates to organic materials. However sediment and debris are often comingles.

Approximately 80 percent of marine debris in the world's oceans originates from land-based sources- primarily trash and debris in stormwater and urban runoff. Studies have found that significant quantities of small plastic debris originating in urbanized land areas pollute the Pacific Ocean both near-shore and on beaches and segments of the ocean thousands of miles away from human habitation.

Studies of debris in Southern California coastal waters demonstrate that significant quantities of trash and debris originate from urban areas and are comprised of pre-production plastics from plastic industrial facilities, trash and litter from urban areas, and boating and fishing-related debris.

More about this topic may be found in the Pollution Prevention and Stormwater-Urban Run Off RMS chapters.

Source: California Coastal Commission and Algalita Marine Research Foundation, n.d.

Box 26-2 Definitions

Suspended load is the portion of the sediment that is carried by a fluid flow which settles slowly enough such that it almost never touches the bed. It is maintained in suspension by the turbulence in the flowing water and consists of particles generally of the fine sand, silt and clay size.

Bed load describes particles in a flowing fluid (usually water) that are transported along the bed of a waterway.

Wash load is the portion of sediment that is carried by a fluid flow, usually in a river, such that it always remains close the free surface (near the top of the flow in a river). It is in near-permanent suspension and is transported without deposition, essentially passing straight through the stream. The composition of wash load is distinct because it is almost entirely made up of grains that are only found in small quantities in the bed. Wash load grains tend to be very small (mostly clays & silts but some fine sands) and therefore have a small settling velocity, being kept in suspension by the flow turbulence.

Box 26-3 Case Study: Sediment Management Related to Recreational Use

Off-highway vehicle (OHV) use is a popular form of recreation in California. State and federal agencies provide recreational areas for this purpose. These OHV recreation areas need to implement a range of storm water best management practices to protect water quality. Additionally, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted storm water. With limited resources, maintaining and policing these areas can be a challenge.

In 2009, the Central Valley Water Board found that portions of the Rubicon Trail located in El Dorado County were severely eroded, erosion was accelerated by OHV use and sediment was being discharged to surface waters. (see following 3 photos provided courtesy Monte Hendricks) To address this problem as well as other OHV related water quality issues, the Central Valley Water Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2009) to El Dorado County and Eldorado National Forest to develop and implement plans to improve management of the trail and protect water quality.

PLACEHOLDER Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

PLACEHOLDER Photo B [title to come]

The Rubicon Trail Foundation, in response to critisms over OHV use of the Rubicon Trail, has been involved in restoration activities and, in testimony to the Central Valley Water Board, provided some photos of improvements. The following three photos (also see pdf of the actual slides from the testimony to the Central Valley Water Board) show before, during and after photos of an eroded site.

In 2012, the Central Valley Water Board found that sediment disturbed by recreational vehicle activity and transported in storm water runoff to Corral Hollow Creek was a water quality problem at the Carnegie State Vehicle Recreation Area. The Board also identified metals, such as copper and lead, as a potential concern. To address these problems, the Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2012) to the California Department of Parks and Recreation (State Parks). The Order recognized that State Parks had developed a Storm Water Management Plan that describes the best management practices that need to be implemented to address erosion and sedimentation. The Order required State Parks to and implement the Storm Water Management Plan update.

PLACEHOLDER Photo C Off-Highway Vehicle — Sediment Settling Pond

— Betty Yee, Central Valley Regional Water Quality Board

Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

[photo to come]

Photo B

[title and photo to come]

Photo C Off-Highway Vehicle — Sediment Settling Pond

[photo to come]

Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

In the 1800s and early 1900s, the Los Angeles Region experienced catastrophic floods that resulted in loss of life and property. Consequently, in 1915, the California State Legislature adopted the Los Angeles County Flood Control Act. The Act established the Los Angeles County Flood Control District and empowered it to provide flood risk management and conserve flood and storm waters. The Flood Control District encompasses most of Los Angeles County, including the highly erosive San Gabriel Mountains as well as other mountain ranges. The Flood Control District operates and maintains 14 dams and reservoirs, 162 debris basins, 500 miles of open channel, and other infrastructure.

Given the region's highly erosive mountains and the existing system, managing flood risk and conserving water goes hand in hand with removing and managing the sediment that accumulates at the facilities. Sediment is delivered to the facilities as a result of runoff in the mountains picking up and carrying material eroded from the mountains. The amount of sediment that reaches a facility any given year depends on the size of the watershed, the watershed's vulnerability to erosion, watershed conditions (such as vegetated watershed versus burned watershed), and weather conditions (such as amount and intensity of rain).

Wildfires greatly increase the amount of runoff and erosion from mountainous watersheds. As much as 120,000 cubic yards of sediment and debris have been produced per square mile of a burned watershed after a major storm. The first four years after a fire have proven to be the most critical in terms of the potential for increased delivery of sediment and debris to the Flood Control District's facilities. The effects of wildfires were taken into consideration during the design of the dams under the jurisdiction of the Flood Control District and continue to be considered for today's operations.

The Station Fire of 2009 was the largest fire in Los Angeles County's recorded history, burning approximately 250 square miles. The fire started on August 26th and was not fully contained until October 16th. The burned watersheds resulted in a significant increase in the amount of sediment and debris eroding from the hillsides during storms and making its way into debris basins and reservoirs. After a short but powerful burst of rain in mid-November 2009, Mullally Debris Basin, which is located in the City of La Cañada-Flintridge and has a 9,400- cubic-yard capacity, filled up in 30 minutes. There were also storms in January and February 2010 that delivered tremendous amounts of sediment to the facilities. The images shown below illustrate the amount of sediment that reached Dunsmuir and Mullally Debris Basins as a result of the Station Fire and the storms of February 2010.

PLACEHOLDER Photos A-D Dunsmuir and Mullally Debris Basins

Immediately following the Station Fire and the 2009-2010 Storm Season, a total of approximately 1.2 million cubic yards (MCY) of sediment were removed from 38 debris basins in order to reduce flood risk for the communities downstream of those debris basins from subsequent storms that still had the potential to send overtopping flows into the debris basins. In addition, many k-rails were installed in the streets of the foothill communities to direct flows away from houses in the event of debris flows due to overtopped debris basins. Emergency operations involved day and night work and trucking of sediment through neighborhoods. The total amount of sediment removed that year is the largest amount removed in any year since the Flood Control District began managing sediment accumulation in debris basins in the 1930s. Notably, the amount of sediment inflow to debris basins is small compared to the amount of sediment that impacts the reservoirs the Flood Control District maintains.

The Station Fire burned significant portions of the watersheds of four reservoirs, as listed below.

- Big Tujunga Reservoir: 88 percent of the reservoir's watershed.
- Cogswell Reservoir: 86 percent of the reservoir's watershed.
- Devil's Gate Reservoir: 68 percent of the reservoir's entire watershed, 92 percent of the reservoir's undeveloped watershed.
- Pacoima Reservoir: 80 percent of the reservoir's watershed.

Based on the Flood Control District's records, 3 of the 4 reservoirs have had an additional 1 MCY of sediment accumulate in them, as detailed in the table below. The potential for high sediment inflows into both reservoirs and debris basins will continue until the watersheds recover.

Table A [title to come]

Reservoir	Date of last survey prior to or soon after Station Fire	Date of last survey [a]	Amount accumulated between subject surveys	Challenges
Big Tujunga	October 2009	August 2011	1.6 MCY	1,2,3,5
Cogswell	December 2009	August 2011	1.7 MCY	1,2,3,5
Devil's Gate	April 2009	March 2011	1.2 MCY	4,5
Pacoima	January 2009	September 2011	0.4 MCY	1,3,4,5

[a] As of June 2012

1 – Limited access ; 2 – Limited space at adjacent or nearby sediment placement sites; 3- Endangered species present downstream; 4- Conflicting environmental interests; 5- Long haul routes to facilities with available space

Another consideration at reservoirs is the amount of sediment already accumulated in them** and the capacity available for additional sediment accumulation that would not interfere with the dam's operations. Given the current volume of sediment and the high potential for large sediment inflows, the Flood Control District is planning sediment removal projects at the four reservoirs affected by the Station Fire. These projects are currently estimated to remove a total of 14 MCY of sediment over the next 8 years, with each project lasting 3 to 5 years and costing as much as $50 million.

** Significant amounts of sediment had accumulated in the subject reservoirs prior to the Station Fire (the same is true of other reservoirs operated and maintained by the Flood Control District). This is the result of a combination of issues, including the following:

- Diverse stakeholder interests, which result in different opinions on the "best" sediment removal, transportation, and placement alternative that should be used for a project.
- Conflicting regulatory requirements.
- Restrictions from other agencies.
- Costs.

— Greg Jaquez, LA Flood Control District

Photos A-D Dunsmuir and Mullally Debris Basins

[photos to come]

Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

Following is story about a proposal to remove a dam (http://www.sandandgravel.com/news/article.asp?v1=13621). While the San Clemente Dam no longer is providing the water supply function it was intended to meet, that may not be true for other dams in the State. For example, LA County has a lot of people (most of its 10 million population) depending on LACFCD's and Corps' dams for flood protection & water supply. This makes a discussion of sediment and dam removal essential to the water management discussion.

News - September 27, 2010

California American Water has filed an application with the California Public Utilities Commission requesting permission to remove the San Clemente Dam on the Carmel River in order to resolve seismic safety concerns associated with the dam and restore critical habitat for the steelhead trout.

"From an engineering and environmental perspective, this is a landmark project," said California American Water president Rob MacLean. "Our innovative method for dealing with the sedimentation behind the dam and the level of public-private cooperation which has made this plan a reality will serve as a template for the removal of other obsolete dams across the country."

California American Water is partnering with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and the California State Coastal Conservancy to implement the dam removal project while minimizing cost to its ratepayers. California American Water has committed $49 million and the dedication of 928 acres where the dam is located as parkland.

The Coastal Conservancy and NOAA committed to raise the additional $35 million needed for the removal project through a combination of public funding and private donations.

The San Clemente Dam is a 106ft high concrete-arch dam built in 1921, 18 miles from the ocean on the Carmel River, to supply water to the Monterey Peninsula's then-burgeoning population and tourism industry. Today the reservoir is over 90 percent filled with sediment and has a limited water supply function.

In 1991, the California Department of Water Resources, Division of Safety of Dams agreed with a California American Water consultant's assertion that San Clemente Dam did not meet modern seismic stability and flood safety standards.

The Department of Water Resources and Army Corps of Engineers studied many ways to ameliorate the safety issues including strengthening the dam and removing it.

The January 2008 Final Environmental Impact Report and Environmental Impact Statement ("EIR/EIS") regarding San Clemente Dam's stability contains analysis of a Reroute and Removal Project, which would address the seismic and flood safety risks associated with San Clemente Dam by permanently rerouting a portion of the Carmel River and removing the dam.

Under this proposal, the Carmel River would be rerouted to bypass the 2.5 million cubic yards of silt that have accumulated behind the dam thereby avoiding dredging, which has been deemed infeasible.

The primary benefits of the Reroute and Removal Project are that it improves the Carmel River environment by removing the dam, which serves as a barrier to fish passage, and satisfies government agencies' concerns that strengthening the dam, as opposed to removing it, could further threaten the South Central California Coast Steelhead and violate the federal Endangered Species Act.

Source: Dredging News Online 2010

Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

The Clear Lake Basin was shaped by a variety of processes over the last 1 to 2 million years. Scientists have recovered a nearly continuous sequence of lake sediments dating back 475,000. Other lake sediments in the region that date back to the Early Pleistocene, approximately 1.6-1.8 million years ago.

There is an excellent climate record from these cores for the last 127,000 years. The record documents a shift from pine dominated to oak dominated forests at the end of the Pleistocene Glacial Period 10,000 years ago, indicating a warming trend. The diatom sequence in these cores indicate that Clear Lake has been a shallow, productive system, essentially similar to the modern lake since the end of the Pleistocene Period.

The basin was created primarily from the stresses of the San Andreas Fault System, the eruption and subsidence of the Clear Lake Volcanics, and the erosion and deposition of the parent rock. The east-west extension of the fault system and vertical movements of the faults created and maintained the basin. Downward vertical movement within the basin created by these processes is at a rate approximately equal to the average sedimentation rate of 1/25 inch/year in the lake basin.

Since these rates are essentially equal, a shallow lake has existed in the upper basin for at least the last 475,000 years. If sedimentation rates were significantly different from the downshift, then either a deepwater lake or a valley would have resulted. Although the lake has changed shape significantly over this period, it has generally been located in the same area as the existing Upper Arm.

Clear Lake is a naturally eutrophic lake. Eutrophic lakes are nutrient rich and very productive, supporting the growth of algae and aquatic plants (macrophytes). Factors contributing to its eutrophication include a fairly large drainage basin to contribute mineral nutrients to the water, shallow and wind mixed water, and no summertime cold water layer to trap the nutrients. Because of the lake's productivity, it also supports large populations of fish and wildlife.

The algae in Clear Lake are part of the natural food chain and keep the lake fertile and healthy. Because of the lake's relative shallowness and warm summer temperatures, the algae serve another important purpose. They keep the sun's rays from reaching the bottom, thus reducing the growth of water weeds which would otherwise choke off the lake.

Along with Clear Lake's high productivity, algae in the lake can create a situation which can be perceived as a problem to humans. Algae are tiny water plants that cycle normally between the bottom and the surface, floating up and sinking down. During the day, algae generate oxygen within the lake; at night they consume oxygen.

Nuisance blue-green algae, however, can be a problem. From more than 130 species of algae identified in Clear Lake, three species of blue-green algae can create problems under certain conditions. These problem blue-greens typically "bloom" twice a year, in spring and late summer. The intensity of the blooms vary from year to year, and are unpredictable. The problem occurs when algae blooms are trapped at the surface and die. When this occurs, unsightly slicks and odors can be produced.

It does not appear that blue-green algae are a recent development in Clear Lake.

Sediment cores collected from the bottom of Clear Lake by the United States Geological Survey (USGS) indicate Clear Lake has been eutrophic with high algal populations since the last ice age, which ended approximately 10,000 years ago. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Algae+Pollen+in+Core.pdf shows the change in algae pollen over time from a core in the Upper Arm.

Livingston Stone, a fisheries biologist, visited Lake County in 1873 and reported to Congress that Clear Lake had significant algal populations at the time.

> It is a singular fact, illustrating the inaptness with which names are often given to natural objects, that the water of Clear Lake is never clear. It is so-cloudy, to use a mild word, that you cannot see three feet below the surface. The color of the water is a yellowish brown, varying indefinitely with the varying light. The water has an earthy taste, like swamp-water, and is suggestive of moss and water-plants. In fact, the bottom of the lake, except in deep places, is covered with a deep, dense moss, which sometimes rises to the surface, and often to such an extent in summer as to seriously obstruct the passage of boats through the water.

He further describes water conditions in September as:

> Fish and fishing are about the same as in August. The weather is a little warmer. No one fishes during this month except the Indians, who still keep after the trout. The water this mouth is in its worst condition. It is full of the frothy product of the soda-springs. A green scum covers a large part of the surface, and it is not only uncleanly to look at, but unfit to drink; and yet, strangely enough, this lake, which one would think uninhabitable by fish, fairly teems and swarms with them.

These descriptions appear to describe blue-green algae and conditions similar to that in the last 20 years. The "moss" described in the first passage could be rooted plants or the filamentous algae *Lyngbya*, which behaves in a similar manner. Regardless, this moss indicates a relatively clear lake if sunlight is penetrating sufficiently to promote growth of "moss" on the bottom. The full text of Stone's writings about Clear Lake are available at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Livingston+Stone.pdf.

Other historical accounts indicate the lake was relatively clear through 1925. Substantial declines in clarity and increases in scum forming algae (blue-green algae) occurred between 1925 and 1939. An increase in nutrient loading from increased erosion, fertilizer and wastewater discharges due to urban and agricultural development were the probable causes of increased blue-green algal growth.

The advent of powered earthmoving equipment increased the amount of soil disturbance and facilitated large construction projects, such as the Tahoe-Ukiah Highway (State Highway 20), the reclamation of the Robinson Lake floodplain south of Upper Lake, stream channelization and the filling of wetlands along the lake perimeter. To support the development, gravel mining increased within the streams , further increasing erosion and sediment delivery to Clear Lake. During this time period, mining techniques at the Sulphur Bank Mercury Mine changed from shaft mining to strip mining, resulting in the discharge of tens of thousands of yards of overburden directly into Clear Lake.

Limnological studies of Clear Lake began in the early 1960's to determine the causes of the high productivity in Clear Lake. It was found that the lake is nitrogen limited in the summer, with a great excess of phosphorus within the system. Phosphorus in the water column comes from both the annual inflows and nutrient cycling from the lake sediments. Nitrogen limitation does not affect many blue-green algae, as they were able to utilize (fix) nitrogen from the atmosphere, and consequently have an essentially unlimited supply of nitrogen. This gave these blue-green algae a competitive advantage, and *Anabaena* and *Aphanizomenon* dominated the lake during the summer. A third blue-green algae, Microcystis, also occurred in significant quantities. During this time period, it was also determined that iron was a limiting micro-nutrient.

Starting in the summer of 1990, lake clarity improved significantly. This improved clarity has continued until the present. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Secchi+Depth$!2c+Upper+Arm.pdf shows the Secchi Depth (the depth into the water at which a black and white checked plate is visible) in the Upper Arm from 1969 through 2008.

During the 1991-1994 time period, University of California researchers led by Drs. Peter Richerson and Thomas Suchanek analyzed lake water quality data collected for the previous 15 years, conducted experiments and evaluated the Clear Lake system. Unfortunately, little data was available during the period of improved clarity since 1990. The "Clean Lakes Report" (http://www.co.lake.ca.us/Assets/WaterResources/Algae/Clean+Lakes+Report$!2c+1994.pdf) determined that excess phosphorus is a major cause, however, iron limits the growth of blue-green algae. The improved water clarity and reduced blue-green algal blooms continued into the new millennium. DWR data collected since the Clean Lakes Report was evaluated by Lake County staff in 2002. Surprisingly, phosphorus and total nitrogen concentrations in the lake did not change substantially when the lake clarity increased. Cursory review of the data did not provide evidence of chemical changes that led to the improved clarity and reduced blue-green algal blooms in Clear Lake.

Source: County of Lake 2010